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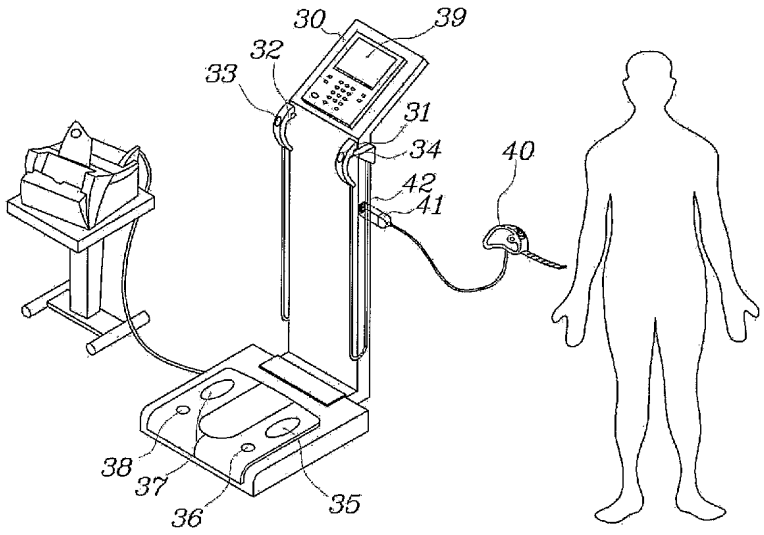

(57) Abstract: The present invention relates to a body fat measuring device using the bio-electrical impedance. More specifically, the invention relates to such segmental bio-electrical body fat measuring device, in which the circumference of body portions or the thickness of subcutaneous fat is measured separately, and then the measured circumference or thickness are used for calculating a segmental body fat more accurately. The segmental body fat measurement device comprises: an impedance measurement circuit (19) including a current electrode and a voltage electrode (31 to 38) to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch (18) for selecting a position in the human body to be measured; an input unit (12) for inputting information such as sex, age and body measurement data of the person to be measured; a display unit (39) for displaying the measurement status and results; a body weight measurement unit (16) for measuring body weight; a CPU (22) for performing a calculation and control function; a circumference scale (40) for measuring the circumference of at least one portion of the human body; a circumference input unit for additionally inputting the measured circumference value, and an output unit for outputting a segmental body fat weight calculated using the circumference value.

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APPARATUS AND METHOD FOR MEASURING SEGMENTAL BODY FAT USING BIOELECTRICAL IMPEDANCE

Technical Field

The present invention relates to a body fat measuring device using the bio-electrical impedance. More particularly, the invention relates to such a segmental bio-electrical body fat measuring device, in which the circumference of body portions or the thickness of subcutaneous fat is measured separately, and then the measured circumference or thickness are used for calculating a segmental body fat more accurately.

Background Art

A bio-electrical impedance method is based on the fact that an electric current flows through water content in the body. The lean body mass contains about 73% of water so that it corresponds to an electrical conductor. Assuming that the cross section of a conductor is constant, the volume V of the conductor, through which the electric current passes has a relationship with the length L of the conductor and the impedance (Z) as follows.

$$V \propto L^2/Z \qquad (I)$$

Thus, the lean body mass weight (FFM) containing a certain content of water has a relationship with the height H_o and the impedance Z as follows.

$$FFM \propto H_o^2/Z \qquad (II)$$

According to this principle, the measurement of the height and the electric resistance over the whole body (e.g. the measurement of the impedance) of a measured person enables his or her lean body mass weight to be calculated. Since the content

of water in the human body is maintained constantly with proportional to the lean body mass, it can be measured in a similar manner. The muscle weight also has a close relationship with the lean body mass weight, and thus can be measured using the same principle.

In contrast, the fat scarcely contains water so that it corresponds to a non-conductor. Thus, dissimilar to the lean body mass, a fat composition cannot be directly measured using the bio-electrical impedance method. However, the sum of a body fat weight and a lean body mass weight corresponds to the body weight, so that the body weight and the lean body mass weight are measured as described above, and the body fat weight can be calculated from the difference between the two measured values. On the other hand, the segmental measurement provides information required for judging the segmental level of muscular development of the measured person. Therefore, it is very useful to identify the effects of segmental exercise, a balance of body, a development level of the upper and the lower body, the effects of rehabilitation treatment, and the like. Similar to the body composition analysis for a whole body, the analysis of segmental body portion such as arms, legs and torso is possible by measuring the segmental impedance therefor. The relationship of the segmental lean body mass weight FFM_i with the height H_o and the segmental impedance Z_i is represented by the following equation.

FFM_i (or segmental muscular weight) H_o^2/Z_i (III)

In the above equation, theoretically, instead of the height, the actual length of each body portion must be applied. For the convenience of measurement, however, replacement of the actual length with the measured height does not make a big difference in its accuracy. Generally, since the human body has a certain length of arms, legs, and torso in proportion to the height, the

commercialized body composition analyzers usually adopt such an assumption.

As one example of a method of measuring a segmental impedance, total 8 electrodes, i.e., 2 electrodes for the respective both hands and feet, are installed to thereby measure an impedance between the distal portions of human body, and calculate a segmental impedance. In such a method, generally, the impedance between the distal body portions, such as hand to hand, foot to foot, left hand to left foot, right hand to right foot, left hand to right foot (diagonal direction), right hand to left foot (diagonal direction), are measured and then the segmental impedance for the 5 body portion of human body can be calculated using a simultaneous equation.

Table: Measurement of segmental human body impedance

	Applied electrode	**Measured body portion**
Measure 1	Left hand, right hand	Left arm + right arm
Measure 2	Left foot, right foot	Left leg + right leg
Measure 3	Left hand, left foot	Left arm + torso + right leg
Measure 4	Right hand, right foot	Right arm + torso + right leg
Measure 5	Left hand, right foot	Left arm + torso + right leg
Measure 6	Right hand, left foot	Right arm + torso + left leg

That is, as shown in the table, after performing 5 or 6 times of measurement from between different distal body portions, which includes a plurality of body portions, the impedance values for the 5 body portions are separately calculated through the simultaneous equation. However such method has a problem in that, in the solution processes of the simultaneous equation, the errors occurred in every measurement are applied equally to

the torso which has a very small impedance value, as compare with arms and legs. The torso occupies a very big portion in the whole body, and thus the errors from near the torso become one of the factors that reduce the accuracy of the entire body composition analysis.

The present inventor has invented a segmental measuring method, in which the defect of such conventional segmental measurement method is improved such that each body portion can be measured directly (Korea Patent No. 10-0161602, United States Patent No. 5,720,296). FIG. 1 shows a modeling of the human body according to the above method. This is not intended to calculate the segmental impedance via the equation, but to measure the impedance of each body portion directly in every measurement. Generally, in the method of measuring impedance, a known magnitude of current is applied and the voltage is measured at the desired body position, and then the Ohm's law is used to obtain impedance. This device is composed of electrodes 1 to 8, an impedance measurement circuit, an electrical switch, an amplifier, an A/D converter, and a CPU. In the conventional segmental measurement, such current and voltage electrodes are always disposed on the same distal portion of human body, however, in the method as proposed above, the position of the electrodes are freely selected, depending on the body portion to be measured.

For example, in order to measure the impedance Z_{ra} of a right arm, the right hand electrode 1 and the right foot electrode 5 are connected to the current terminal, and another right hand electrode 2 and the left hand electrode 4 are connected to a voltage terminal. Therefore, the impedance measurement can be carried out at the right hand portion where a current flowing site and a voltage measuring site exist at the same time. In order to measure the impedance Z_t of the torso,

the right hand electrode 1 and the right foot electrode 5 are connected to the current terminal, and the left hand electrode 4 and the left foot electrode 8 are connected to the voltage terminal. In case of the impedance Z_{rf} of the right foot, the right hand electrode 1 and the right foot electrode 5 are connected to the current terminal, and the right foot electrode 6 and the left foot electrode 8 are connected to the voltage terminal. The impedance of a left arm and a left leg can be measured by switching the above-described procedures for the right hand and the right leg. This method is in principle based on the theory that the voltage drop occurs only where the actual electric current flows. This segmental impedance measurement method does not make unnecessary propagation of the error, which arises during the solution of the simultaneous equation. In addition, by measuring the desired portion of body independently, it can measure impedance of the torso, which is relatively difficult to measure due to respiration, heartbeat and others.

On the other hand, a body composition measurement method of torso portion such as abdominal visceral fat or subcutaneous fat is disclosed in Japanese Patent Application No. 99-164633 or 99-164634. In order to calculate the amount of abdominal visceral and subcutaneous fat, the circumference of the abdomen and abdominal visceral fat is directly measured. The abdominal fat distribution is calculated from the direct measurement of circumference and subcutaneous fat, in accordance with the fact that the total fat weight has a relationship with the visceral and entire abdominal fat. That is, a total fat weight is obtained by measuring the bio-impedance, and the abdominal fat area is calculated using the inter-relationship between abdominal fat area and the total fat weight. In the above applications, although the abdominal fat distribution is obtained by direct measuring the thickness and circumference of

subcutaneous fat in the impedance measurement, it only use the relationship between the abdominal fat and the total body fat, but can not obtain the segmental body fat distribution.

On the other hand, in the bio-electrical impedance method, in principle, the segmental measurement of body can be achieved because the body fat weight is obtained by subtracting the lean body mass from the total fat and the segmental weight of individual body portion cannot be calculated. Since the outline of shape and physique of a measured person can be predicted from the weight or height by considering sex, age, and the like, a method of estimating a segmental body fat weight is occasionally used, which includes experience and statistical prediction values. By the measurement of segmental impedance as described above, the internal body shape of a measured person, that is, the distribution of lean body mass can be identified. Furthermore, a general segmental body fat distribution of the measured person may be estimated from the fact that the body fat distribution has a general tendency, depending on the total body fat weight, sex, and age. However, the above statistical predicted value also is not always accurate for each individual measured person so that the measured segmental body fat may include lots of errors in many cases.

Disclosure of Invention

The present invention has been made in order to solve the above problems occurring in the prior art, and it is an object of the invention to provide a body shape measurement method, in which a measurement of circumferences of body portion or thickness of subcutaneous fat is further performed by means of a circumference scale or a skin-fold calipers in addition to a body composition analyzer, thereby more accurately measuring the

segmental body fat weight, and measuring the body shape by calculating the subcutaneous fat weight of body.

Another object of the invention is to measure a segmental fat distribution more precisely, as compared with a conventional bio-impedance method in the measurement of segmental body fat weight, by further providing a direct measurement of the circumference or the thickness of subcutaneous fat for a specific body portion such as a torso or a leg.

The inventor has discovered the fact that the entire body fat distribution is estimated with greater precision by additionally measuring the circumference or thickness of subcutaneous fat for a specific body portion such as abdomen, in addition to the conventional segmental body fat measurement using an impedance measurement method. Generally, since the subcutaneous fat is distributed in such a way as to surround uniformly the lean body mass component, the measurement of circumference or thickness of subcutaneous fat provides exact information about the body shape by predicting the segmental body fat distribution, particularly in such as arms and legs, and calculating the segmental subcutaneous fat weight.

In order to accomplish the above objects, according to one embodiment of the invention, there is provided a segmental body fat measurement device using a bio-electrical impedance. The segmental body fat measurement device includes: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight

measurement unit 16 for measuring body weight; a CPU 22 for performing a calculation and control function; a circumference scale 40 for measuring the circumference of at least one portion of the human body; a circumference input unit for additionally inputting the measured circumference value, and an output unit for outputting a segmental body fat weight calculated using the circumference value.

In addition, according to the first embodiment of the invention, the body portion where its circumference is measured includes at least one selected from the group consisting of an upper arm, a leg, and an abdomen.

In addition, according to the first embodiment of the invention, the circumference measurement is carried out using an electronic tape measurer, and the measured data is automatically input.

In addition, according to the first embodiment of the invention, the circumference measurement is carried out using non-contacting light interference, and the measured data is automatically input.

In addition, according to the first embodiment of the invention, the electronic tape measurer is constructed such that it can be separated from the main body of the body fat measurement device.

In addition, according to the first embodiment of the invention, the output unit further outputs a segmental subcutaneous fat weight.

According to the first embodiment of the invention, there is provided a method of measuring a segmental body fat measurement device using a bio-electrical impedance. The method includes the steps of: a) measuring a segmental lean body mass weight using a segmental body fat measurement device, which includes: an impedance measurement circuit 19 including a

current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function; b) measuring a circumference of at least one portion of the human body; and c) calculating a circumference of a body portion where its circumference is not measured.

In addition, according to the first embodiment of the invention, there is provided a method of measuring a segmental body fat measurement device using a bio-electrical impedance. The method includes the steps of: a) measuring a segmental lean body mass weight using a segmental body fat measurement device, which includes: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function; b) measuring a circumference of at least one portion of the human body; c) calculating a circumference of a body portion where its circumference is not measured; d) calculating a segmental subcutaneous fat and

thickness from the segmental circumference and the segmental lean body mass weight.

On the other hand, according to the second embodiment of the invention, there is provided a segmental body fat measurement device using a bio-electrical impedance including: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; a CPU 22 for performing a calculation and control function; a subcutaneous fat measurement meter 40 for measuring a thickness of a subcutaneous fat of at least one body portion; a subcutaneous fat input unit for further inputting the measured thickness of subcutaneous fat into the CPU 22; and an output unit 11 for outputting a segmental body fat weight calculated using the thickness of subcutaneous fat.

In addition, according to the second embodiment of the invention, the body portion where its subcutaneous fat is measured includes at least one selected from the group consisting of an upper arm, a leg, and an abdomen.

In addition, according to the second embodiment of the invention, the measurement of subcutaneous fat is carried out using a skin-fold caliper or a near infrared method, and the measured data is automatically input.

In addition, according to the second embodiment of the invention, the subcutaneous fat measurement meter is constructed such that it can be separated from the main body of the body fat

measurement device.

In addition, according to the second embodiment of the invention, the output unit further outputs a segmental circumference calculated.

According to the second embodiment of the invention, there is provided a method of measuring a segmental body fat measurement device using a bio-electrical impedance. The method includes the steps of: a) measuring a segmental lean body mass weight using a segmental body fat measurement device, which comprises an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function; b) measuring a thickness of subcutaneous fat of at least one body portion; and c) calculating, from the measured lean body mass weight, a thickness of subcutaneous fat of a body portion where its thickness of subcutaneous fat is not measured.

In addition, according to the second embodiment of the invention, there is provided a method of measuring a segmental body fat measurement device using a bio-electrical impedance. The method includes the steps of: a) measuring a segmental lean body mass weight using a segmental body fat measurement device, which includes: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an

current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function; b) measuring a thickness of subcutaneous fat of at least one body portion; c) calculating, from the measured lean body mass weight, a thickness of subcutaneous fat of a body portion where its thickness of subcutaneous fat is not measured; and d) calculating a segmental circumference from the segmental thickness of subcutaneous fat and the lean body mass weight.

In addition, according to the third embodiment of the invention, there is provided a segmental body fat measurement device using a bio-electrical impedance including: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; a CPU 22 for performing a calculation and control function; a subcutaneous fat measurement meter 45 for measuring a thickness of a subcutaneous fat of at least one body portion; a circumference scale 40 for measuring the circumference of at least one portion of the human body; a subcutaneous fat input unit and a circumference input unit for further inputting the measured

thickness of subcutaneous fat and the measured circumference into the CPU 22; and an output unit 11 for outputting a segmental body fat weight calculated using the circumference and the thickness of subcutaneous fat.

Brief Description of Drawings

Further objects and advantages of the invention can be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a modeling of the human body showing the positions for the electrode to be contacted, and an impedance model;

FIG. 2 is a schematic block diagram showing the construction of a body fat measurement device using a bio-electrical impedance according to a first and a second embodiment of the invention;

FIG. 3 is a specific example showing the body fat measurement device using a bio-electrical impedance according to the first embodiment of the invention;

FIG. 4 is a schematic diagram showing a conventional non-contacting laser interference measurement device;

FIG. 5 is a specific example showing the body fat measurement device using a bio-electrical impedance according to the second embodiment of the invention;

FIG. 6a shows a method of measuring the thickness of sebum using a skin-fold caliper;

FIG. 6b is a cross-section of a corresponding body portion showing the method of measuring the thickness of sebum using the skin-fold caliper;

FIG. 7 is a model showing the body water and the body fat in a body portion;

FIG. 8 shows a flow chart of a method of measuring a

segmental body fat using a bio-electrical impedance according to the first embodiment of the invention;

FIG. 9 shows a flow chart for segmental subcutaneous fat weight and thickness measurement method using the bio-electrical impedance body fat measurement device according to the first embodiment of the invention;

FIG. 10 shows a flow chart of a method of measuring a body fat weight using the bio-electrical impedance according to the second embodiment of the invention;

FIG. 11 shows a flow chart of a method of measuring a segmental circumference of body portion using the body fat measurement method according to the second embodiment of the invention; and

FIG. 12 is a specific example showing the body fat measurement device using a bio-electrical impedance according to the third embodiment of the invention.

Best Mode for Carrying Out the Invention

The preferred embodiments of the present invention will be hereafter described in detail with reference to the accompanying drawings.

FIG. 2 is a schematic block diagram showing the construction of a body fat measurement device using a bio-electrical impedance according to a first and a second embodiment of the invention. FIG. 3 is a specific example showing the body fat measurement device using a bio-electrical impedance according to the first embodiment of the invention. Similar to a general common method, the impedance measurement is composed of an impedance measurement circuit 19 including electrodes 31 to 38 to be contacted with feet and hands, an current application circuit and a voltage application circuit, an electronic switch 18 for selecting a position in the human

body to be measured, an input unit 12 having a keypad for inputting information such as sex, age and body measurement data of a person to be measured, a display unit 39 for displaying the measurement status and results, a body weight measurement unit 16 for measuring body weight, amplifiers 20, 23, and 24, an A/D converter 21, and a CPU 22 for performing a calculation and control function. FIG. 3 shows a main body 30 and a circumference scale 40, and the circumference scale 40 is for measuring the circumference of a body portion to be measured and calculating the thickness of subcutaneous fat through the measurement the circumferences.

In order to measure a bio-impedance according to the invention, prior to its measurement, a person to be measured (hereinafter, referred to as a "measured person") inputs his or her information such as sex, age, height, and the like. Measurable information such as height may be input automatically using a separate measuring device such as an ultrasonic stadiometer or a displacement meter. In addition, the personal data card (not shown), which stored personal information such as sex, age and health record, can be read in a body composition analyzer. It is to be appreciated that those skilled in the art can change or modify these input devices without departing from the scope and spirit of the present invention.

After finishing all data input, when the measured person holds left hand electrodes 32, 33 and right hand electrodes 31, 34 with both hands, and steps on right foot electrodes 35, 36 and left foot electrodes 37, 38, the weight of the measured person can be measured by a weight sensor (not shown) under the feet electrodes. In order to measure impedance, a known level of current is applied, a voltage is measured in a desired portion, and impedance is then calculated in accordance with the Ohm's law. The impedance is measured by using a device including the

electrodes 31 to 38, the impedance measurement circuit 19, the electronic switch 18, the amplifiers 20, 23 and 24, the A/D converter 21, and the CPU 22. In the conventional segmental measurement, such current and voltage electrodes are disposed on the same position, however the electrodes are disposed flexibly depending on the measurement position in the proposed method. By measuring the desired portion directly in a separate way, errors from above-described existing simultaneous equation can be decreased.

On the other hand, the method of measuring a circumference of a body portion using the circumference scale is intended to allow the measuring person to measure the circumferences of the particular portion of the measured person, as shown in FIG. 3. Since this is a method for measuring directly the circumferences, the accurate value of the circumference of the portion to be measured can be obtained. As a method to measure the circumferences, a manual scale can be employed. However, as disclosed in Korean Patent Laid-open Publication No. 2003-21812 and Korean Utility Model Laid-open Publication No. 1999-37565, the electronic scales may be employed, in which an optical sensor or encoder is used to measure the circumferences and the values is converted into electrical signals. The measured values by the above-described electronic scale are input to the body composition analyzer either manually or automatically, and the segmental body fat distribution is measured. Thus, the measured circumference value is transmitted to the CPU by inputting to body composition analyzer using a keypad. Alternatively, as shown in FIG. 3, the electronic scale is connected directly to the body composition analyzer through the connection terminal 42 such that the measured values can be transmitted automatically to the CPU.

In addition, the measurement of circumference is carried

out by a non-contacting laser interference method. The non-contacting laser interference measurement device is generally a 3-dimensional laser scanner, which is known as a technique to measure the coordinates of a body shape or a 3-dimensional object, and disclosed in detail in U.S. Patent No. 4737032 or Japanese Patent Laid-open Publication No. Hei3-194414. As shown in FIG. 4, a planar beam is irradiated to a target object or the human body, and the reflected beam from the surface thereof is reflected again by reflectors 61 and 62. The reflected beam is used to measure the coordinates of the 3-dimensional surface using the interference phenomenon from a transmitting reflector 63. The body-shape measurement technology has been well known, and thus details thereon will not be described here, however the circumference values obtained from the 3-dimensional shape measurement can be employed in the invention.

In addition, the electronic scale is preferably provided with a connection terminal at one side of the main body 30 of the body fat measurement 30 so that the electronic scale can be separated from the main body 30. The connection terminal 42 for transmitting the circumference value can be provided separately in one side of the main body, however it can be transmitted through various connection ports such as the existing printer connection port (parallel: IEEE1284), RS232C, USB, and the like.

The total body water content is the sum of water contents in each portion of the body, and represented as the following equation.

$$TBW = a_1H_o^2/Z_{ra} + a_2H_o^2/Z_{la} + a_3H_o^2/Z_t + a_4H_o^2/Z_{ra} + a_5H_o^2/Z_{la} \quad (IV)$$

Here, ra represents a right arm, la represents a left arm, t represents a torso, rl represents a right leg, ll represents a left leg, and a_1, a_2, a_3, a_4 and a_5 represent constants to satisfy the equation IV with an optimum condition, and is determined through the regression analysis. The equation IV is programmed

in the CPU 22. Among the composition of the human body, the body fat contains an extremely small amount of water so that it can be neglected. Since the lean body mass composition contains 73% of the water, the lean body mass weight, which corresponds to the water content divided by 0.73.

In order to obtain the segmental lean mass (SLM), the following equations are employed.

$$SLM_{ra} = b_{1ra} \times Z_{ra} + b_{2ra} \times W_o + b_{3ra} \times H_o + b_{4ra}$$

$$SLM_{la} = b_{1la} \times Z_{la} + b_{2la} \times W_o + b_{3la} \times H_o + b_{4la}$$

$$SLM_t = b_{1t} \times Z_t + b_{2t} \times W_o + b_{3t} \times H_o + b_{4t} \quad \text{(V)}$$

$$SLM_{rl} = b_{1rl} \times Z_{rl} + b_{2rl} \times W_o + b_{3rl} \times H_o + b_{4rl}$$

$$SLM_{ll} = b_{1ll} \times Z_{ll} + b_{2ll} \times W_o + b_{3ll} \times H_o + b_{4ll}$$

Here, W_o represents a body weight.

In the equation (V), the constant values b_{1i}-b_{4i} (where i represents a body portion such as ra, la, t, rl or ll) are obtained from a plurality of measured persons using an instrument having a segmental measurement function such as a dual energy x-ray absorptiometry (DEXA). A regression model is used in order to obtain an optimum value meeting the reference value. The accomplished formula is stored in the CPU.

If the segmental lean mass is obtained, the circumference value of the muscle is calculated based on the cylindrical model of FIG. 7. That is, FIG. 7 shows a cylindrical model of each body portion, which is based on the anatomic foundation that the subcutaneous fat surrounds the outside of the cylindrical muscle. The segmental lean mass volume (V_i) is represented by the following equation.

$$V_i = \frac{\pi D_i^2}{4} \times L_i \quad \text{(VI)}$$

Here, L_i represents the length of a segmental body. If the circumference value of inner muscle is denoted by Cl_i (inner

circumference) in the cylindrical model, the volume of muscle (V_i) is expressed by the following equation.

$$V_i = \frac{CI_i^2}{4\pi} \times L_i \quad \text{(VII)}$$

Thus, the segmental circumference of muscle CI_i is expressed as follows.

$$CI_i = \sqrt{\frac{SLM_i \times 4\pi}{L_i}} \quad \text{(VIII)}$$

Assuming that the body portion is not an exact cylindrical shape and the length of the segmental portion is proportional to the height, the above equation is calibrated and thus the segmental circumference of muscle can be obtained by the following equation.

$$CI_i = c_{1i}\sqrt{\frac{SLM_i \times 4\pi}{L_i}} + c_{2i} \quad \text{(IX)}$$

On the other hand, the segmental body fat mass (SFM_i) is as follow.

$$SFM_i = \frac{CO_i^2 - CI_i^2}{4\pi} \times L_i \quad \text{(X)}$$

Here, CO_i represents the circumference of a body portion. Assuming that fat has even distribution on each segmental body and the length is proportional to the height, it is calibrated as the following equation.

$$SFM_i = d_{1i}\frac{CO_i^2 - CI_i^2}{4\pi} \times H_O + d_{2i} \quad \text{(XI)}$$

The calibration constant d_{1i} and d_{2i} are calibrated with the amount of segmental body fat through the instrument such as DEXA.

The addition of the sum of SFM_i obtained from a segmental body and the fat weight of head corresponds to the total body

fat weight. The assumption that the head has a constant body fat weight is often used.

At the body portion where the circumference is not measured, the segmental body fat weight can be obtained from the fact that the sum of SFM_i is the total body fat weight. If distribution of fat in the human body is divided into three parts of arms, legs and torso, by measuring the value of the two portions with the circumference scale, the rest is obtained by excluding the measured portions from the total weight. Also, in case of where one portion is measured, then the rest of the other two sites can be measured by using the empirical variables. In this case, since the body fat weight of one portion, a value with high precision can be expected, as compared with the case of not measuring separately using a circumference scale.

In this way, if the segmental body weight is obtained, from the difference between the outside circumference and he circumference of muscle, the segmental subcutaneous fat skin fold SF_i can be calculated by the following equation.

$$SF_i = \frac{CO_i - CI_i}{\pi} \qquad \text{(XII)}$$

In view of the above measurement processes, the segmental body fat weight can be calculated accurately by measuring the circumference of muscle and a body portion using the impedance method.

As body portions for measuring the circumference, one or more portions such as an upper arm, a thigh, a chest, an abdomen, and the like are selected, and, if needed, a particular portion can be selected for the measurement.

FIG. 8 shows a flow chart of a method of measuring a segmental body fat using a bio-electrical impedance according to the first embodiment of the invention. The method includes the steps of: measuring a segmental lean body mass weight using the

bio-electrical impedance measurement device (S100), measuring the circumference of at least one body portion (S110), and carrying out an arithmetic operation for obtaining a circumference value from the measured lean body mass weight regarding a body portion where the circumference is not measured (S120). When required, a step of outputting a segmental body fat value (S130) may be included. The bio-electrical impedance measurement device, as described above, is based on the segmental body fat measuring device shown in FIG. 2, from which the segmental lean body mass weight is obtained. In addition, the circumference scale is employed to measure the circumference directly, and at the body portion where its circumference is not measured, the segmental body fat weight can be obtained, considering the fact that the sum of segmental body fat weight is the total body fat weight. In other word, the body portion where the circumference is not measured is obtained by excluding the measured portion from the total fat weight.

FIG. 9 shows a flow chart for segmental subcutaneous fat weight and thickness measurement method using the bio-electrical impedance body fat measurement device according to the first embodiment of the invention. The method includes the steps of: measuring a segmental lean body mass weight using the bio-electrical impedance measurement device (S200); measuring the circumference of at least one body portion (S210), carrying out an arithmetic operation for obtaining a circumference value of the body portion where the circumference is not measured (S220); and carrying out an arithmetic operation for obtaining segmental subcutaneous fat weight and thickness (S240). The bio-electrical impedance measurement device, as described above, is based on the segmental body fat measuring device shown in FIG. 2, from which the segmental lean body mass weight is obtained. In addition, the circumference scale is employed to measure the

circumference directly, and at the body portion where its circumference is not measured, the segmental body fat weight can be obtained by excluding the measured body portion from the total fat weight. Finally, the above equation (XII) is employed to obtain the segmental subcutaneous fat weight through an arithmetic operation.

The second embodiment of the present invention will be hereinafter described. FIG. 5 shows a specific example of the bio-electrical impedance body fat measurement device according to the second preferred embodiment. The impedance measurement is the same as described above. However, the main body 30 and a skin-fold calipers 40 for measuring the thickness of subcutaneous fat at a localized body portion are shown in FIG. 5, the skin-fold caliper is a circular scale used to measure the thickness of subcutaneous fat and is widely used in the body fat measurement (a skin-fold thickness method) or in determining nutrition conditions.

On the other hand, in the method of measuring the thickness of subcutaneous fat using the skin-fold calipers, as shown in FIGS. 6a and 6b, the dermal surface at a specific localized portion of a measured person is slightly pinched up such that the subcutaneous fat 50 is double-folded, and then the thickness thereof is measured. In order to seize the subcutaneous fat, only the surface and subcutaneous fat except muscle and muscular membrane is pinched. Then, the skin-fold caliper is installed in the position where is 1 cm apart from the finger and a scale of skin-fold calipers is read. Since this is a practical method of measuring directly the thickness of subcutaneous fat, the accurate thickness of subcutaneous fat where the portion to be measured can be obtained. Thus, the measured thickness of subcutaneous fat is transmitted to the CPU by inputting it to the body composition analyzer using the keypad of the input

device. Alternatively, as shown in FIG. 5, the electronic skin-fold calipers may be connected directly to the body composition analyzer through the connection terminal 42 such that the measured values can be transmitted automatically to the CPU.

As a method of measuring the thickness of subcutaneous fat, along with the skin-fold calipers, near infrared or ultrasound can be used. Here, the segmental body fat distribution can be measured by measuring the thickness of subcutaneous fat, and the value is input to the body composition analyzer either manually or automatically.

In addition, the above skin-fold calipers is provided such that it can be separated from the main body by including a connection terminal at one side of the main body 30 of the body fat measurement device using bio-electrical impedance. The connection terminal 42 for transmitting the measurement value from the skin-fold calipers can be provided at one side of the main body separately, however the measurement value can be transmitted through the existing various connection ports such as a printer connection port (Parallel: IEEE1284), RS232C, USB and the like.

On the other hand, when based on the cylindrical model of FIG. 7, the segmental fat mass SFM_i is expressed by the following equation.

$$SFM_i = \left(CI_i + \frac{\pi SF_i}{2} \right) \times \frac{SF_i}{2} \times L_i \qquad (X')$$

Here, SF_i represents the fold-thickness of subcutaneous fat as shown in the figure. Assuming that fat has a uniform distribution in each segmental body portion and the length is proportional to the height, the equation X' is calibrated as follows.

$$SFM_i = d_{1i}\left(CI_i + \frac{\pi SF_i}{2}\right) \times \frac{SF_i}{2} \times H_o + d_{2i} \qquad \text{(XI')}$$

The calibration constants d_{1i} and d_{2i} are calibrated with the segmental fat mass through an instrument such as DEXA.

The addition of the sum of SFM_i obtained from segmental body portions and the body fat weight of the head corresponds to the total body fat weight. The assumption that the head has a constant body fat weight is often used.

At the body portion where the thickness of subcutaneous fat is not measured, the segmental body fat weight can be obtained from the fact that the sum of SFM_i is the total body fat weight. If distribution of fat in the human body is divided into three parts of arms, legs and torso, by measuring the value of the two portions with the skin-fold caliper, the rest is obtained by excluding the measured portions from the total weight. Also, in case of where one portion is measured, then the rest of the other two sites can be measured by using the empirical variables. In this case, since the body fat weight of one portion, a value with high precision can be expected, as compared with the case of not measuring separately using a skin-fold caliper.

In this way, if the segmental body fat weight is obtained, considering the thickness of fat surrounding muscle, the segmental outer circumference CO_i can be calculated by the following equation.

$$CO_i = CI_i + \pi SF_i$$

$$= CI_i + e_{1i}\sqrt{\frac{SFM_i}{L_i}} + e_{2i}$$

$$= CI_i + f_{1i}\sqrt{\frac{SFM_i}{H_o}} + f_{2i} \qquad \text{(XII')}$$

By pre-setting the constant such as f_{1i} and f_{2i} so as to match to the segmental outer circumference, which is measured by a scale in advance, the segmental outer circumference can be obtained. In view of the above measurement processes, the segmental body fat weight can be obtained by only the segmental thickness measurement (skin-fold calipers). That is, it is because although the thickness of subcutaneous fat is identical at all the portions, the total fat weight has a different value, in the case where the arm circumference is big or small. However, the segmental body fat weight can be calculated accurately by measuring the circumference of muscle and the inner circumference using the impedance method as in present invention.

As body portions for measuring the circumference, one or more portions such as an upper arm, a thigh, a chest, an abdomen, and the like are selected, and, if needed, a particular portion can be selected for the measurement.

FIG. 10 shows a flow chart of a method of measuring a body fat weight using the bio-electrical impedance according to the second embodiment of the invention. The method of this embodiment includes the steps of: measuring the segmental lean body weight using the bio-electrical impedance measurement device (S300), measuring the thickness of subcutaneous fat of at least one body portion (S310), carrying out an arithmetic operation for obtaining the thickness of subcutaneous fat of a body portion where its thickness of subcutaneous fat is not measured from the measured lean body mass weight (S320). The method, if required, may include a step of outputting the segmental body fat value (S330). The bio-electrical impedance measurement device, as described above, is based on the segmental body fat measuring device shown in FIG. 2, from which the segmental lean body mass weight is obtained. In addition, the skin-fold calipers can be employed to measure the thickness

of subcutaneous fat directly, and at the body portion where its thickness is not measured, the segmental body fat weight can be obtained, considering the fact that the sum of segmental body fat weight is the total body fat weight. In other word, the body portion where its thickness is not measured is obtained by excluding the measured portions from the total fat weight.

FIG. 11 shows a flow chart of a method of measuring a segmental circumference of body portion using the body fat measurement method according to the second embodiment of the invention. The method of this embodiment includes the steps of: measuring a segmental lean body mass weight using the bio-electrical impedance measurement device (S400); measuring the thickness of subcutaneous fat of at least one body portion (S410); carrying out an arithmetic operation for obtaining the thickness of subcutaneous fat at the body portion where the thickness of subcutaneous fat is not measured from the measured lean body mass weight (S420); and carrying out an arithmetic operation for obtaining a segmental circumference of body portion (S440). The bio-electrical impedance measurement device, as described above, is based upon the segmental body fat measuring device shown in FIG. 2, from which the segmental lean body mass weight is obtained. In addition, the skin-fold calipers can be employed to measure the thickness of subcutaneous fat directly, and at body portion where cannot be measured by the skin-fold calipers, it can be obtained by excluding the measured body portions from the total fat weight. Finally, the above equation (XII') can be employed to obtain the segmental circumference through an arithmetic operation.

Finally, the third embodiment of the present invention will be hereafter described. As shown in FIG. 12, the third embodiment of the present invention includes an impedance measurement circuit 19 including a current and voltage

electrodes 31 to 38 to be contacted with the hands and feet of a measured person, a current application circuit, and a voltage measurement circuit, an electronic switch 18 for selecting a portion of human body to be measured, an input unit 12 having a keypad for inputting information such as sex, age and body measurement data of the measured person, a display unit 39 for displaying the measuring status and results, a body weight measurement unit 16 for measuring the body weight of the measured person, and a CPU 22 for performing calculation and control. It further comprises a subcutaneous fat measure meter 45 for measuring the thickness of subcutaneous fat of at least one body portion using bio-electrical impedance, a circumference scale 40 for measuring the circumference of at least one body portion, a subcutaneous fat and circumference input unit for inputting additionally the measured circumference and thickness of subcutaneous fat to the CPU 22, and an output unit 11 for outputting a segmental body fat weight calculated using the circumference and thickness of subcutaneous fat. That is, the circumference scale 40 and subcutaneous fat measurement meter 45 are employed to measure one or more portion of the body, so that the segmental body fat weight can be more accurately obtained by using the above equations XI' and XI.

Industrial Applicability

As described above, according to the invention, a segmental body fat weight can be obtained accurately by measuring a segmental impedance and a segmental circumference or a subcutaneous fat thickness. Although the circumference or the thickness of subcutaneous fat is not measured over the whole body, the unmeasured remaining portion can be predicted.

According to the invention, a segmental impedance and a segmental body fat weight are obtained so that a segmental

subcutaneous fat weight can be accurately calculated, thereby identifying the characteristic of the human body.

While the present invention has been described with reference to the particular illustrative embodiments, it is not to be restricted by the embodiments but only by the appended claims. It is to be appreciated that those skilled in the art can change or modify the embodiments without departing from the scope and spirit of the present invention.

What Is Claimed Is:

1. A segmental body fat measurement device using a bio-electrical impedance comprising: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; a CPU 22 for performing a calculation and control function; a circumference scale 40 for measuring the circumference of at least one portion of the human body; a circumference input unit for additionally inputting the measured circumference value, and an output unit for outputting a segmental body fat weight calculated using the circumference value.

2. The segmental body fat measurement device according to claim 1, wherein the body portion where its circumference is measured includes at least one selected from the group consisting of an upper arm, a leg, and an abdomen.

3. The segmental body fat measurement device according to claim 1, wherein the circumference measurement is carried out using an electronic tape measurer, and the measured data is automatically input.

4. The segmental body fat measurement device according to claim 1, wherein the circumference measurement is carried out

using non-contacting light interference, and the measured data is automatically input.

5. The segmental body fat measurement device according to claim 3, wherein the electronic tape measurer is constructed such that it can be separated from the main body of the body fat measurement device.

6. The segmental body fat measurement device according to claim 1, wherein the output unit further outputs a segmental subcutaneous fat weight.

7. A method of measuring a segmental body fat measurement device using a bio-electrical impedance, the method comprising the steps of:

a) measuring a segmental lean body mass weight using a segmental body fat measurement device (S100), the segmental body fat measurement device comprising: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function;

b) measuring a circumference of at least one portion of the human body (S110); and

c) calculating a circumference of a body portion where its circumference is not measured (S120).

8. The method according to claim 7, wherein the body portion where its circumference is measured includes at least one selected from the group consisting of an upper arm, a leg, and an abdomen.

9. The method according to claim 7, wherein the circumference measurement is carried out using an electronic tape measurer, and the measured data is automatically input.

10. A method of measuring a segmental body fat measurement device using a bio-electrical impedance, the method comprising the steps of:

a) measuring a segmental lean body mass weight using a segmental body fat measurement device (S200), the segmental body fat measurement device comprising: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function;

b) measuring a circumference of at least one portion of the human body (S210);

c) calculating a circumference of a body portion where its circumference is not measured (S220);

d) calculating a segmental subcutaneous fat and thickness from the segmental circumference and the segmental

lean body mass weight (S240).

11. A segmental body fat measurement device using a bio-electrical impedance comprising: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; a CPU 22 for performing a calculation and control function; a subcutaneous fat measurement meter 40 for measuring a thickness of a subcutaneous fat of at least one body portion; a subcutaneous fat input unit for further inputting the measured thickness of subcutaneous fat into the CPU 22; and an output unit 11 for outputting a segmental body fat weight calculated using the thickness of subcutaneous fat.

12. The segmental body fat measurement device according to claim 11, wherein the body portion where its subcutaneous fat is measured includes at least one selected from the group consisting of an upper arm, a leg, and an abdomen.

13. The segmental body fat measurement device according to claim 11, wherein the measurement of subcutaneous fat is carried out using a skin-fold caliper or a near infrared method, and the measured data is automatically input.

14. The segmental body fat measurement device according

to claim 11, wherein the subcutaneous fat measurement meter is constructed such that it can be separated from the main body of the body fat measurement device.

15. The segmental body fat measurement device according to claim 11, wherein the output unit further outputs a segmental circumference calculated.

16. A method of measuring a segmental body fat measurement device using a bio-electrical impedance, the method comprising the steps of:

a) measuring a segmental lean body mass weight using a segmental body fat measurement device (S300), the segmental body fat measurement device comprising: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function;

b) measuring a thickness of subcutaneous fat of at least one body portion (S310); and

c) calculating, from the measured lean body mass weight, a thickness of subcutaneous fat of a body portion where its thickness of subcutaneous fat (S320) is not measured.

17. The method according to claim 16, wherein the body portion where its subcutaneous fat is measured includes at least

one selected from the group consisting of an upper arm, a leg, and an abdomen.

18. The method according to claim 16, wherein the measurement of subcutaneous fat is carried out using an electronic skin-fold caliper or a near infrared method, and the measured data is automatically input.

19. A method of measuring a segmental body fat measurement device using a bio-electrical impedance, the method comprising the steps of:

a) measuring a segmental lean body mass weight using a segmental body fat measurement device (S400), the segmental body fat measurement device comprising: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; and a CPU 22 for performing a calculation and control function;

b) measuring a thickness of subcutaneous fat of at least one body portion (S410);

c) calculating, from the measured lean body mass weight, a thickness of subcutaneous fat of a body portion where its thickness of subcutaneous fat (S420) is not measured; and

d) calculating a segmental circumference from the segmental thickness of subcutaneous fat and the lean body mass weight.

20. A segmental body fat measurement device using a bio-electrical impedance comprising: an impedance measurement circuit 19 including a current electrode and a voltage electrode 31 to 38 to be contacted with a foot and hand of a person to be measured, an current application circuit and a voltage application circuit; an electronic switch 18 for selecting a position in the human body to be measured; an input unit 12 for inputting information such as sex, age and body measurement data of the person to be measured; a display unit 39 for displaying the measurement status and results; a body weight measurement unit 16 for measuring body weight; a CPU 22 for performing a calculation and control function; a subcutaneous fat measurement meter 45 for measuring a thickness of a subcutaneous fat of at least one body portion; a circumference scale 40 for measuring the circumference of at least one portion of the human body; a subcutaneous fat input unit and a circumference input unit for further inputting the measured thickness of subcutaneous fat and the measured circumference into the CPU 22; and an output unit 11 for outputting a segmental body fat weight calculated using the circumference and the thickness of subcutaneous fat.

FIG. 1

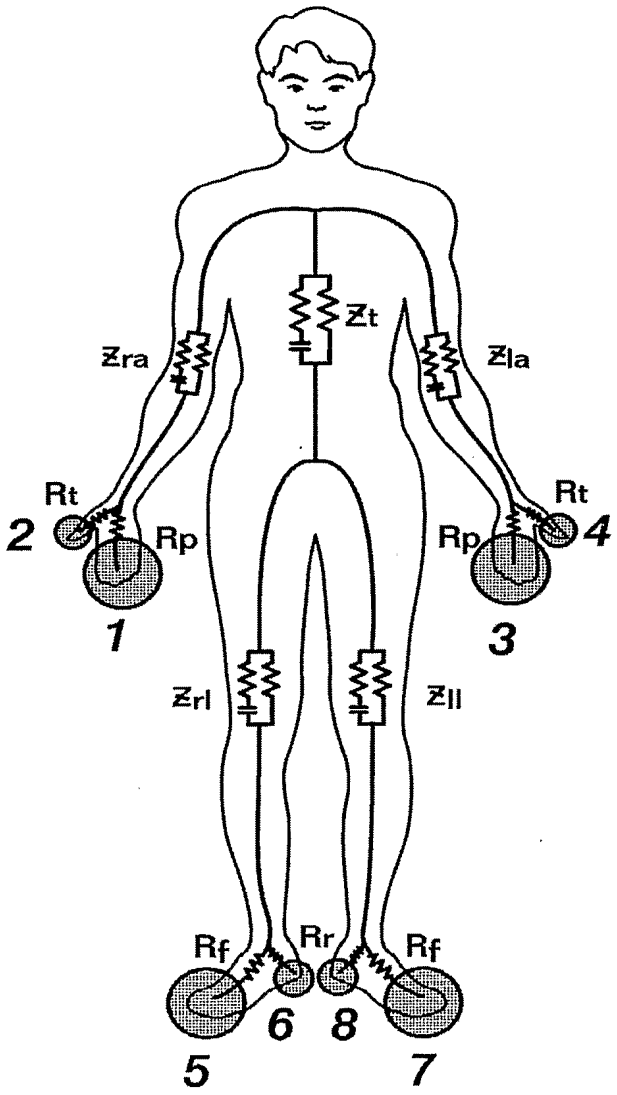
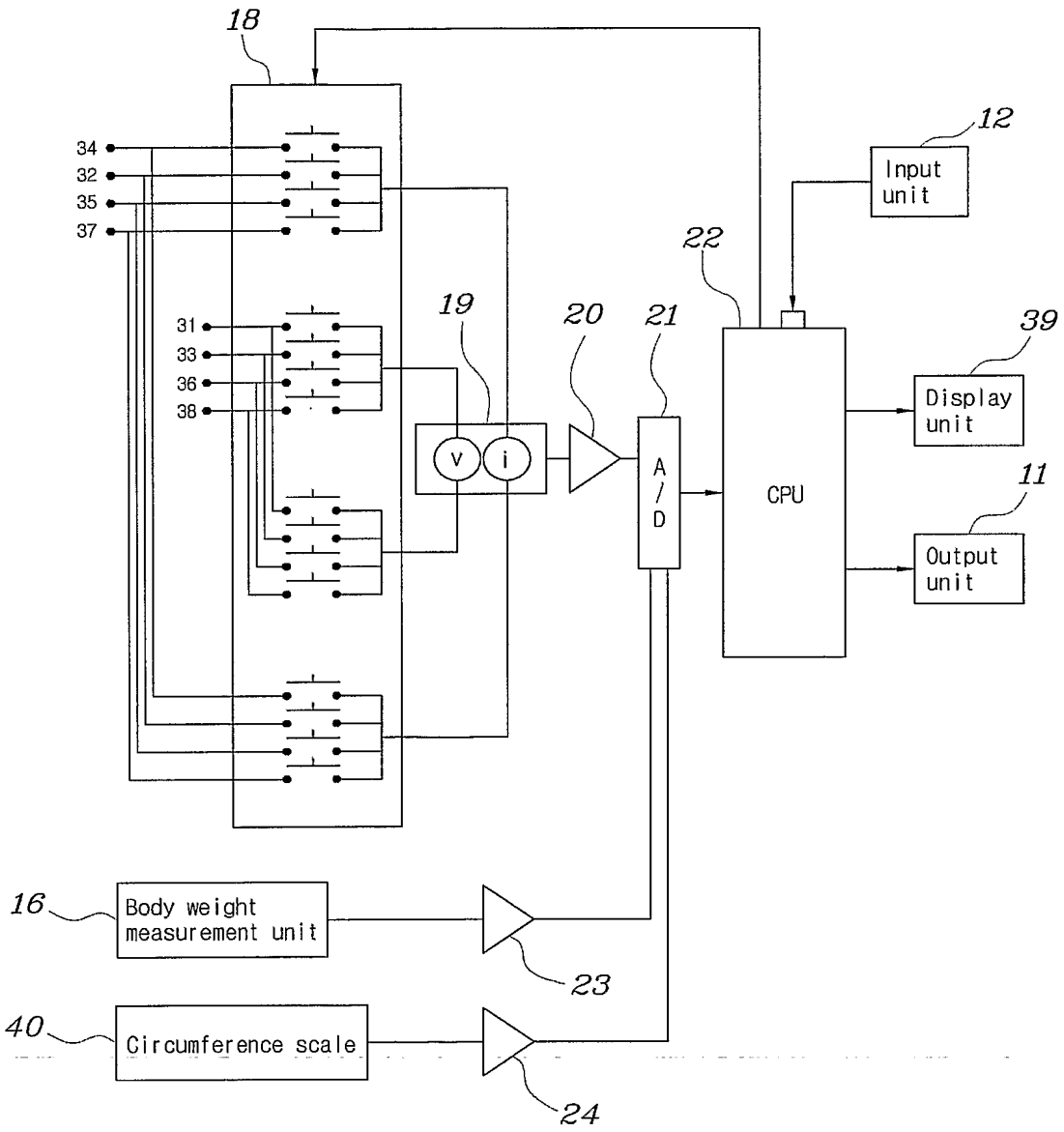


FIG. 2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33
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20
21
22
12
Input unit
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Display unit
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Output unit
V
i
A / D
CPU
16
Body weight measurement unit
23
40
Circumference scale
24

FIG. 3

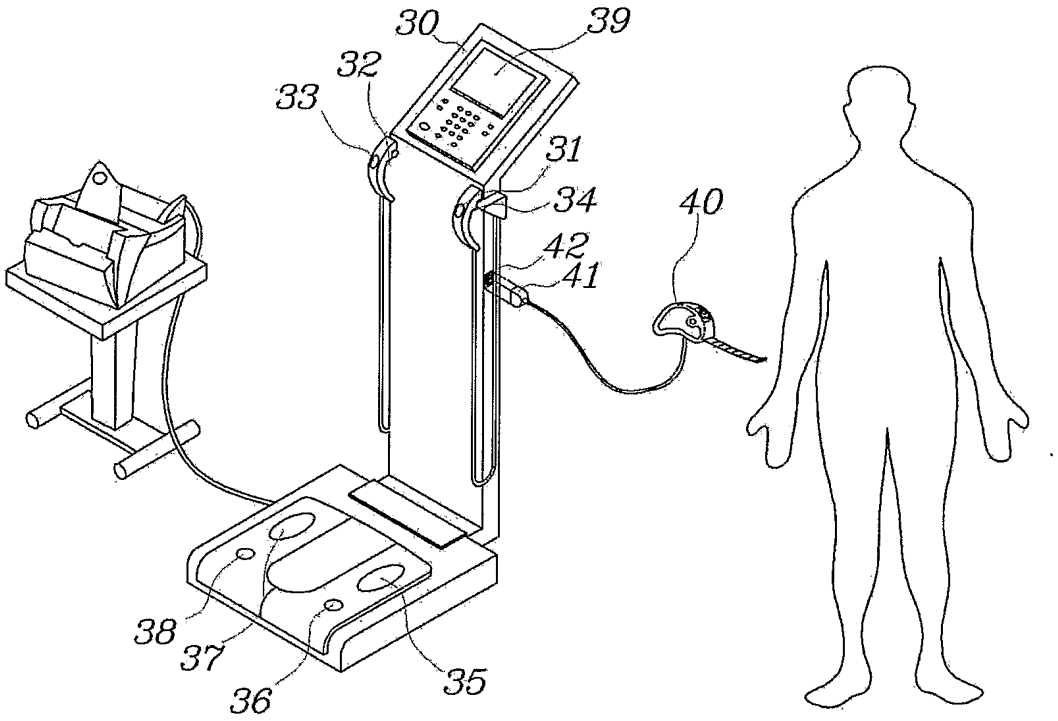


FIG. 4

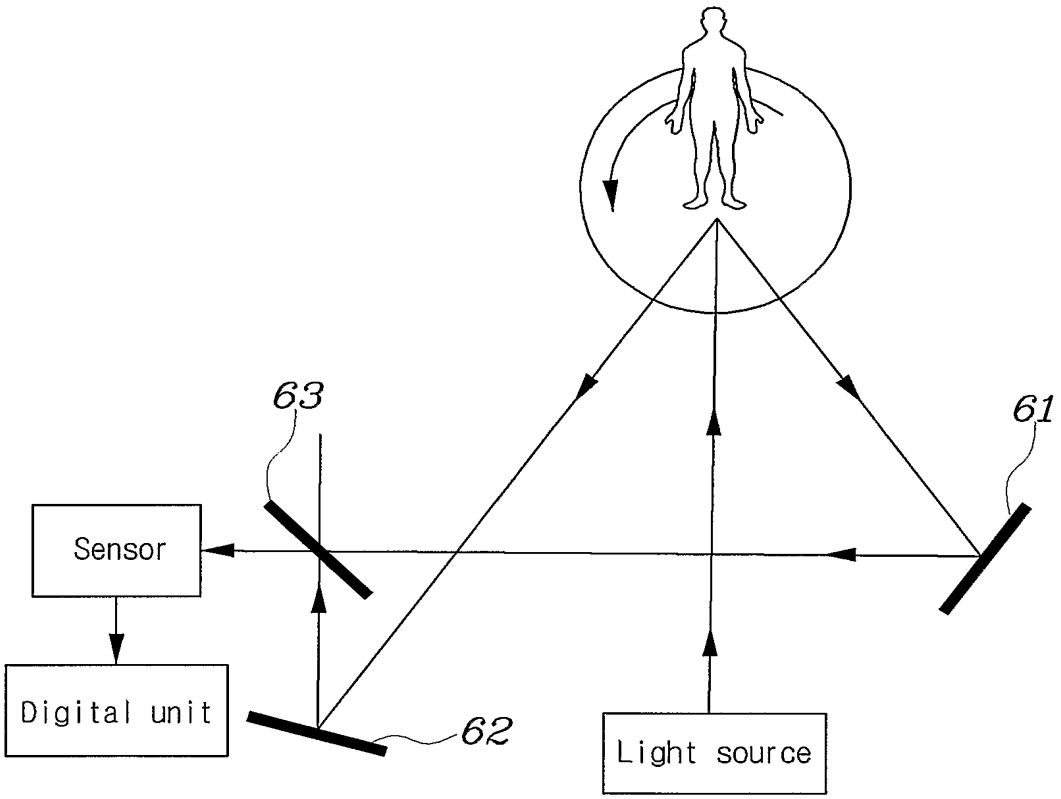


FIG. 5

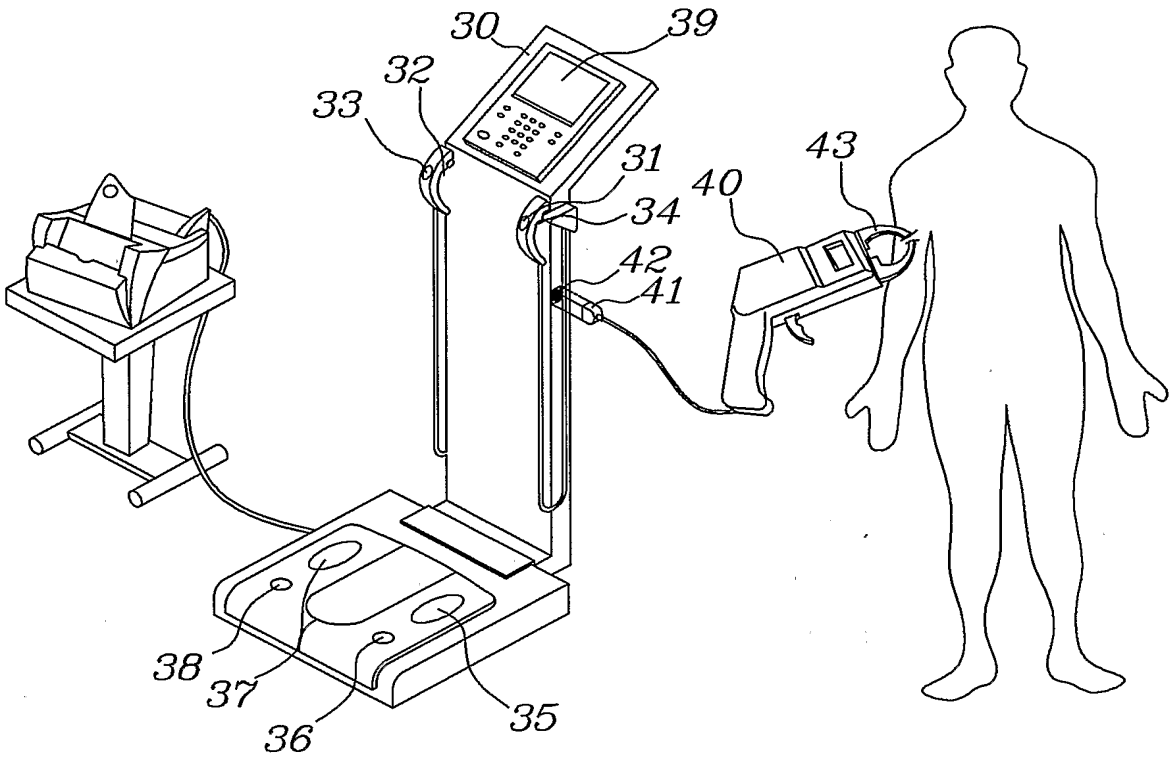


FIG. 6a

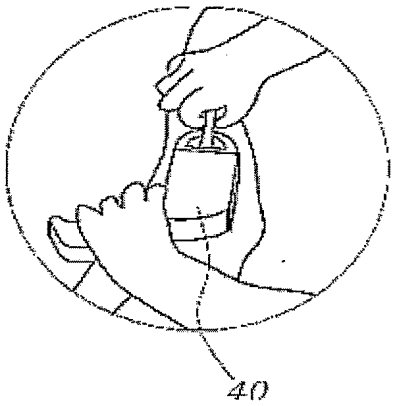


FIG. 6b

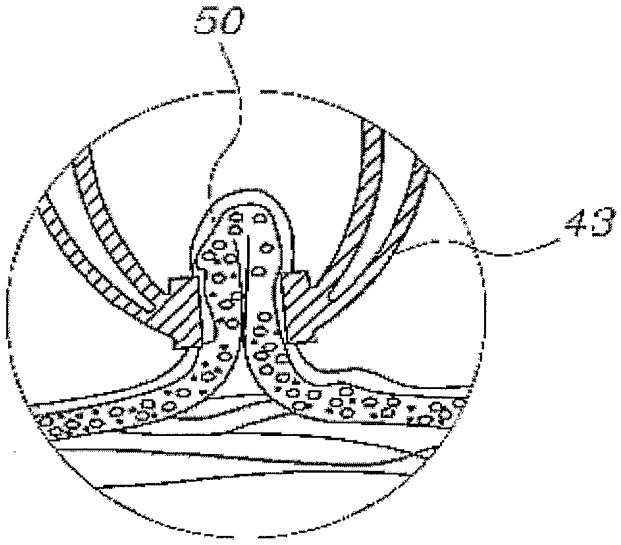


FIG. 7

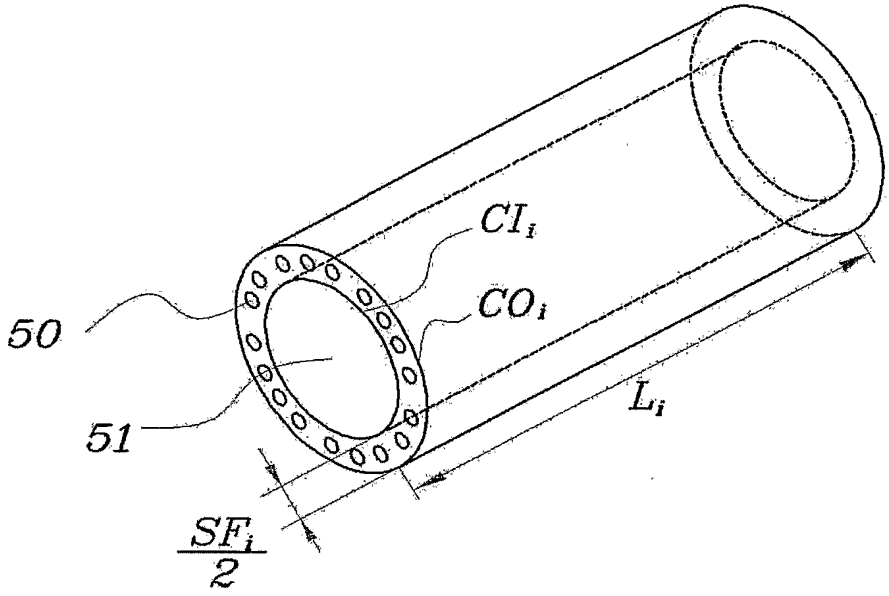

50
51
CI_i
CO_i
L_i
$\frac{SF_i}{2}$

FIG. 8

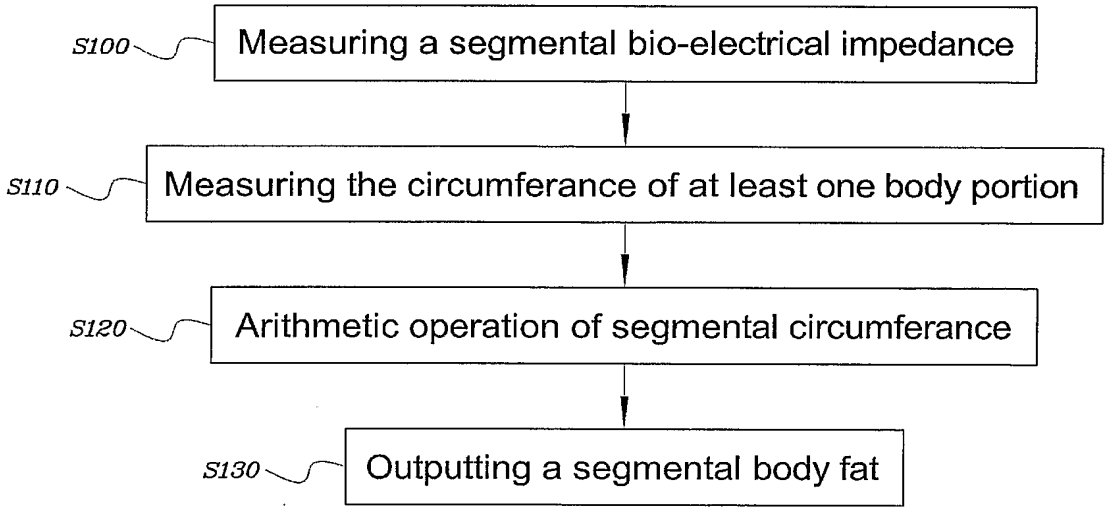

S100
Measuring a segmental bio-electrical impedance
S110
Measuring the circumferance of at least one body portion
S120
Arithmetic operation of segmental circumferance
S130
Outputting a segmental body fat

FIG. 9

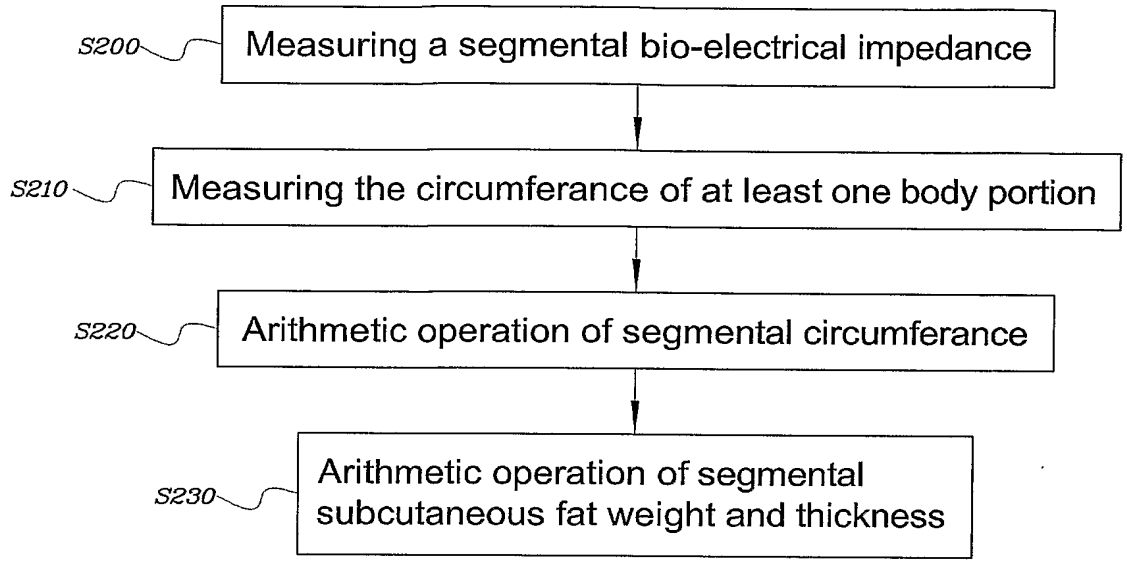

S200
Measuring a segmental bio-electrical impedance
S210
Measuring the circumferance of at least one body portion
S220
Arithmetic operation of segmental circumferance
S230
Arithmetic operation of segmental subcutaneous fat weight and thickness

FIG. 10

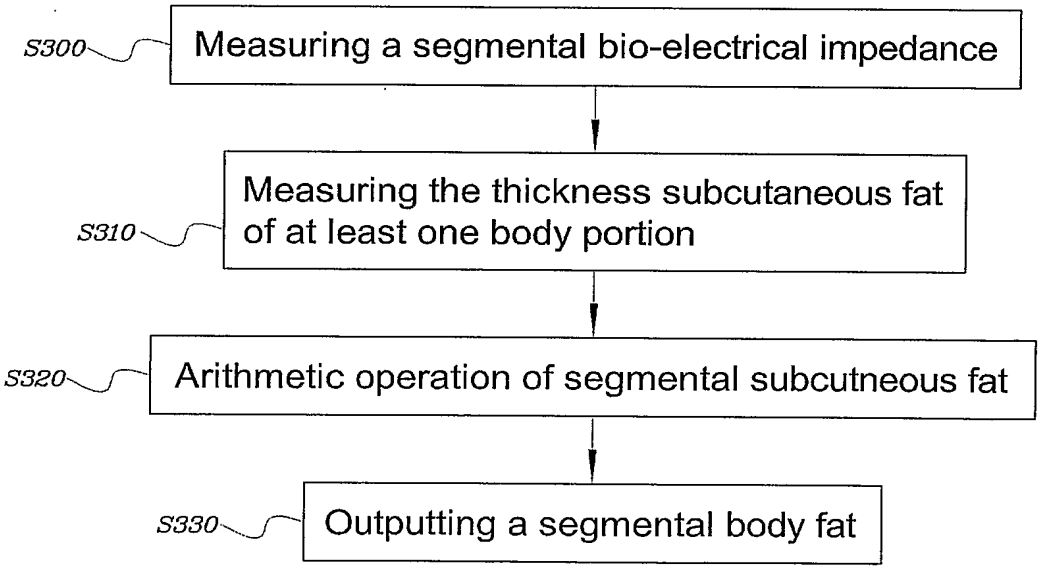

S300
Measuring a segmental bio-electrical impedance
S310
Measuring the thickness subcutaneous fat of at least one body portion
S320
Arithmetic operation of segmental subcutneous fat
S330
Outputting a segmental body fat

FIG. 11

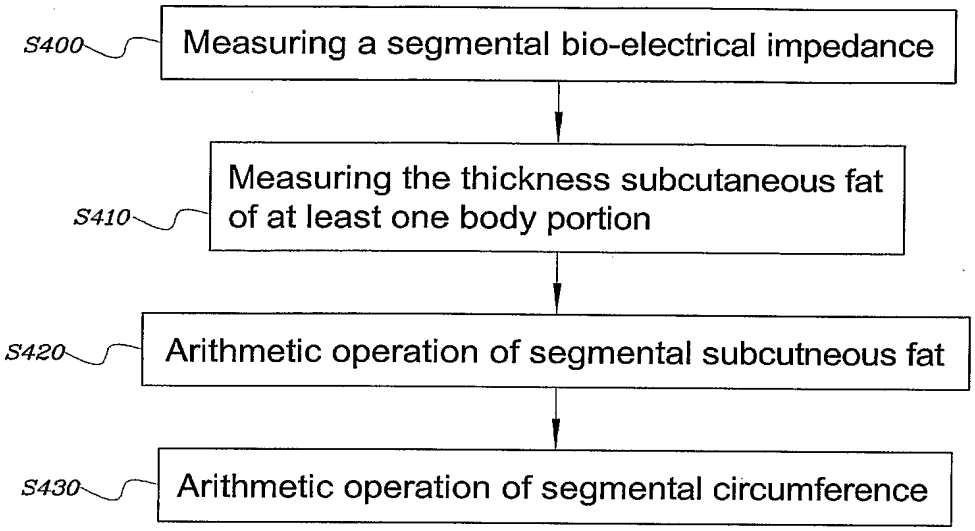
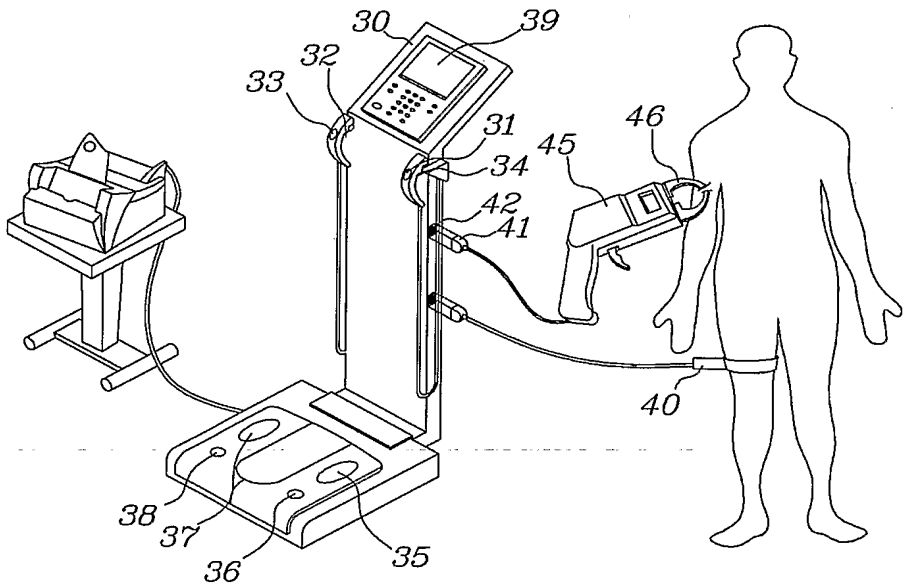

S400
Measuring a segmental bio-electrical impedance
S410
Measuring the thickness subcutaneous fat of at least one body portion
S420
Arithmetic operation of segmental subcutneous fat
S430
Arithmetic operation of segmental circumference

FIG. 12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INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2004/000135

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 A61B 5/053

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC7 A61B 5/053

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Patents and applications for inventions since 1975
Korean Utility models and applications for Utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 2003-21812 A (PARK YOUNG CHOOL) 15 MARCH 2003 See whole documemt	1-3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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